Embodied AI for Financial Literacy Social Robots

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***Abstract*—Financial literacy is a critical field that prepares individuals to manage their money effectively and to become economically self-sufficient by making informed financial decisions. As artificial intelligence (AI) becomes more widespread across a variety of disciplines, including K-12 education, and more financial institutions move towards digitizing their services, the demand for AI systems in financial literacy education is growing. While many financial and educational institutions alike have implemented AI systems, there remains a need for a system geared toward teaching young students these important lessons and skills. To address this demand, we have created an AI system equipped with financial literacy lessons for grade school students. The system, which is embedded into a NAO robot, a humanoid robot designed for use within education, was evaluated on its performance in the classroom across multiple metrics, including its efficacy, its robustness and feasibility in the classroom, and the students' enjoyment in using it. The results from the experiments suggest that the system did result in the retention of material, but did not do so at a significantly different level than the more traditional teaching method of a guided worksheet. However, the students did report higher levels of enjoyment in using the robot when compared to a worksheet. These results show promise for future uses of the system, as well as shed light on areas in which the system can be improved in the future.**

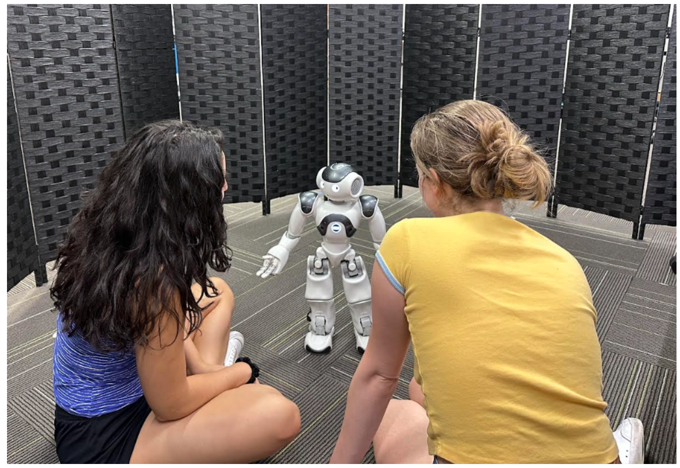

Fig. 1. A NAO robot, as used in our experimental study, interacting with students in an example scenario.

I. Introduction

Artificial intelligence (AI) is being used increasingly across the world, with many applications ranging from grocery store self-checkout systems to healthcare to robotics [1]–[9]. Nearly a $100 billion industry already, the global AI market is expected to make great strides, expanding at an estimated compound annual growth rate (CAGR) of over 38% by 2030 [10]. Due to its wide number of applications and versatility, AI can and is being used across virtually any discipline.

According to research conducted by Su & Yang, AI tools are increasingly being used in the early childhood education (ECE) sphere [11]. A reported 92% of academic institutions have already implemented AI systems for a variety of different purposes, a primary motivation of which is to help improve learning by increasing engagement and offering personalized learning experiences [12]. There is also hope that AI systems can address the current teacher burnout crisis the U.S. is facing by reducing the burden on educators [13]. Moreover, some experts believe children should be engaging with an AI curriculum as a key aspect of modern digital literacy lessons in a rapidly developing digital world [14]. Research done by Druga et al. shows that the already-existing digital divide between racial minority and dominant groups has been deepened in the realm of AI technologies [15]. These researchers claim there is an urgent need for the promotion of AI in the classroom to attain digital equity and close the observed divide.

An important area of study in which AI systems could stand to improve upon students' learning experiences is financial literacy. The importance of financial education lies in its ability to equip individuals with the skills necessary to make informed financial decisions throughout their lives. These lessons can be even more impactful when they are introduced at a young age. Research conducted by the National Financial Educators Council found that individuals who receive financial education at a young age are more likely to save money, have higher credit scores, and make better decisions regarding debt and investments [16]. Additionally, studies show that individuals who receive financial education in grade school are more likely to save for retirement and avoid high-cost borrowing options, such as payday loans [17]. By teaching young students lessons about how to budget, save, and invest, financial education can empower them to make informed decisions that can lead to long-term financial stability.

Despite the importance of financial education, many Americans are not adequately prepared to make sound financial decisions. Research by Klapper et al. found that only 57% of adults in the United States are financially literate [18]. Furthermore, only 17% of Americans are considered to have high financial literacy, and a majority of Americans struggle with basic financial concepts [19]. Still, only 21 U.S. states require a personal finance class for high school students before they graduate, and such classes are very seldom taught in

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middle and elementary schools [20].

As younger generations enter adulthood, financial institutions are adapting to meet their changing needs and preferences. As this new age of clientele has grown up in an increasingly digital world, financial institutions are making the logical step towards further digitizing their services. Many financial institutions are utilizing AI to assist, onboard, and educate their younger clientele in an effort to close the generational wealth gap [21]. The use of AI technology can help to meet the expectations of seamless, user-friendly digital experiences.

To address the growing demand for AI in financial education, our team has developed a prototype for an embedded educational AI system. This system is equipped with a financial literacy lesson on credit aimed toward teaching fourth-grade students. The goal of this project was to embed an artificially intelligent lesson plan into a humanoid robot and then analyze its performance in a classroom setting. The prototype was developed by building upon the work of a team from the University of Virginia who created an AI voice assistant system equipped with two financial literacy lessons for grade school students [22]. The AI system was adapted for use in a robot and embedded into a NAO robot: a humanoid robot designed for use within education, as seen in Fig. 1.

After testing the prototype in a classroom environment compared against a more traditional guided worksheet lesson plan, we were able to draw conclusions about the system's performance in terms of efficacy and robustness, as well as the level of enjoyment reported by the students who participated in the study. Our analysis showed both the robot and the guided worksheet lesson plans improved students' comprehension of the material, but neither method was significantly better than the other at doing so. Additionally, students reported higher levels of enjoyment of the lesson as administered by the robot. The analysis also revealed areas in which the system could be improved, including delivery of and aid in solving math problems. Overall, the prototype's performance showed promising results for future iterations.

II. Prior Work

There are a wide variety of educational AI systems being implemented across the globe currently. For example, some research found that 92% of academic institutions are already regularly using AI systems in their lessons [12]. A system recently developed by researchers in Mexico utilized Google Dialogflow, a Google Cloud Platform-powered service employed in the development of our prototype, to develop a virtual assistant that is able to help students with frequently asked questions in a course. While the methodology of the system they created could be applied to any course, the prototype they created for this study was completed for four classes in an undergraduate program [23].

Other existing educational applications for voice assistants include acting as a social partner for special education students, a foreign language learning aid, and a variety of tools to help primary and secondary school educators. The latter category, of which our prototype falls, includes systems capable of taking attendance, grading assignments, automatically generating practice content, answering frequently asked questions, and more [24]. However, many of these applications remain as proposed ideas or as first iterations of prototypes, untested in a classroom environment. Studies have also been administered to explore future educational capabilities for voice assistants, including assisting students with autism [25], improving web page information accessibility [26], and providing in-person practice experiences for students in online classes [27]. While each of these existing studies provides important insight into the potential educational usage of AI systems, our research provides a unique understanding of the methodology of implementing a humanoid robot with young students in classrooms.

A similar prototype was developed and tested in two second-grade classrooms in Taiwan in 2014. This study developed and tested an educational robot equipped with the ability for teachers to input instructional content and multimedia objects into a lesson to be delivered by the system. However, in this study, the control group against which the robot's performance was compared was a PowerPoint presentation lesson, which requires an instructor to carry out [28]. In our study, the control group consisted of a guided worksheet designed to be self-paced and carried out with minimal intervention from an instructor. The selection of a guided worksheet as the control group allowed us to compare our prototype with another self-paced, mostly instructor-less method.

The system we built used the lesson plans of an artificially intelligent voice assistant system created by a team at the University of Virginia, in collaboration with MITRE [22]. The previously built system was designed to teach financial literacy lessons to students. The creation of this team's prototype involved three main components: lesson plan content generation, cloud platform implementation, and system evaluation. The system they created was tested and declared satisfactory in its baseline performance in effectiveness and robustness. The team recommended additional research about and modifications to both the system and the lessons it taught [22].

III. Methodology

The execution of the prototype was divided into four vital components, as broken down into corresponding phases: planning the experimental study, embedding the AI system into a robot, executing the study in the classrooms, and evaluating the system's performance.

A. Phase 1: Planning the Experimental Study

The objective of this experiment was to test the viability and efficacy of using a NAO robot in financial education. We first surveyed local elementary schools to identify potential participants. This initial outreach included a series of virtual Zoom meetings explaining how the lesson plans were generated using The National Standards in K-12 Personal Finance Education benchmarks [29]. Additional meetings were held to cover the optimal methodology to conduct the study given the schools' structure; i.e., selection criteria for which grade to study, number of participating classrooms, duration

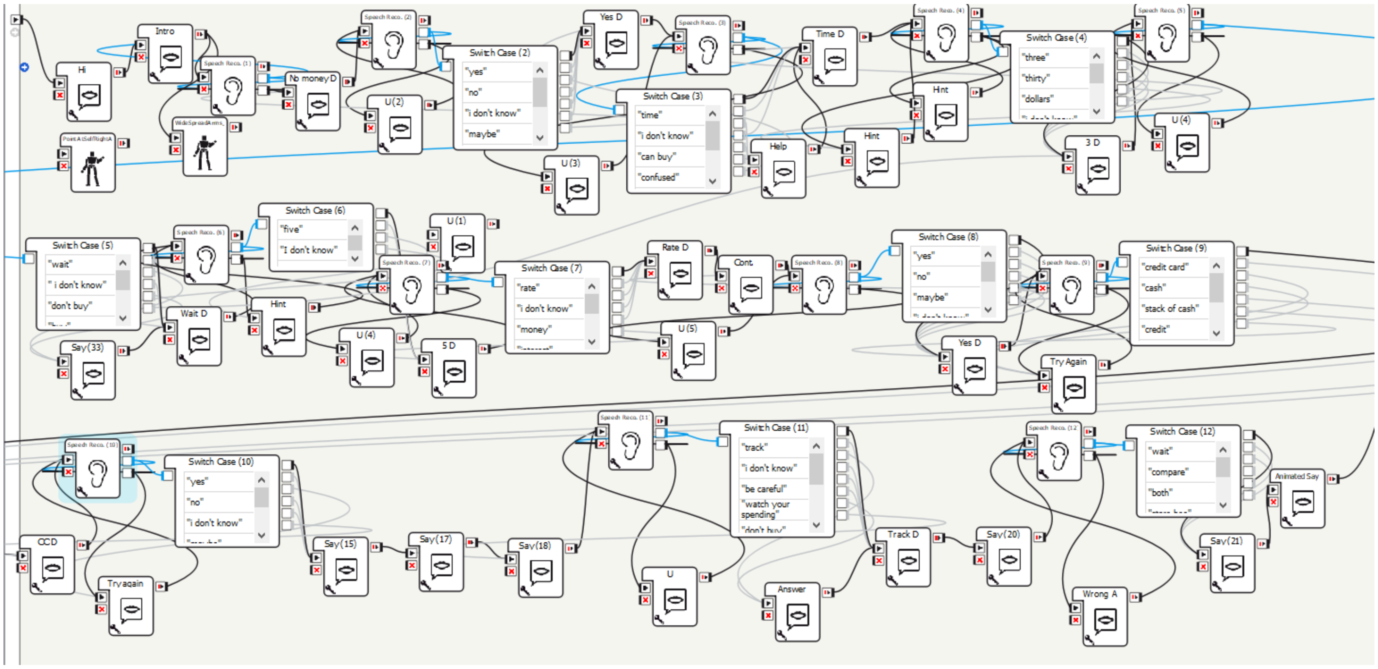

Fig. 2. An example of the artificially intelligent lesson plan on credit as implemented in the Choregraphe software.

of the study, etc. Following extensive discussions with 10 local schools, two fourth-grade classrooms at Greer Elementary School, Charlottesville, VA, were selected to participate in the study.

In addition to selecting participant groups, another aspect of planning the experimental study was securing approval from the Institutional Review Board (IRB) for conducting research on human subjects. This process involved providing the IRB committee with a protocol including a detailed plan of our experiment, the subjects involved, the data to be collected, and the lessons to be administered. This step in the process also involved getting consent from the parents of the participants in the study. Once our IRB protocol was approved, we could proceed with testing in the chosen elementary school.

B. Phase 2: Embedding the AI System into a Robot

The next objective was to convert the credit and debit lesson plan, originally developed in Google DialogFlow, into Choregraphe: a software application designed for programming NAO robots. In the process of transferring, we encountered a few obstacles, including adapting the conversational flows, customizing the robot's speech and voice, and handling user input. An example of a block of the lesson plan as implemented in Choregraphe can be seen in Fig. 2.

Prior research on this topic included conversational flows that were developed and tested on college students. For the purpose of this experiment, we had to alter some of the languages in the lesson plans to make them understandable for fourth-grade students. We accomplished this by including examples in the lesson plans which were more suitable to the age group we would be testing the system with.

The default voice for DialogFlowCX integrations, as used in the previous experimental research, sounds more human-like than that of the NAO robot, making it easier to understand. As a result, as well as the fact that the participants in this study are much younger, we chose to slow down the NAO robot's speech and change the inflection in order to make comprehension as easy as possible for the average fourth grader.

Finally, we had to handle user input. In DialogFlow, the lesson was set up with "intent match," which is a built-in feature of the software that utilizes AI to interpret the user's intent based on their input. DialogFlow's AI then automatically follows the conversation path it believes will allow the user to best progress through the lesson. In order to be prepared for all responses, including unexpected responses or questions, we utilized prior research data and training phrases to better understand the ways in which users may phrase their questions and statements. We also created hints and offered the ability to repeat questions and concepts to ensure the most fluid, responsive conversations possible.

C. Phase 3: Executing the Study in the Classroom

The experimental study was aimed at determining the viability and efficacy of the system created by comparing the performance of a class taught by the robot with that taught by a guided worksheet. The study was conducted in two fourth-grade classrooms, one of which with 11 students was randomly assigned to be the experimental group, interacting with NAO robots equipped with the aforementioned financial literacy lesson plan. The other classroom of 15 students was subsequently assigned to be the control group, partaking in a guided worksheet with an identical lesson to that taught by

TABLE I
QUESTIONS INCLUDED ON THE PRE-TEST AND POST-TEST, AS USED TO MEASURE STUDENTS' COMPREHENSION OF THE MATERIAL PRESENTED IN THE LESSON PLANS. THE TABLE DISPLAYS THE CORRECT ANSWER TO EACH MULTIPLE-CHOICE QUESTION, AS WELL AS THE OTHER 3 INCORRECT ANSWER CHOICES.

Question	Correct Answer	Other Answer Choices		
Why might someone choose to purchase something in multiple payments?	They don't have enough money	They want to buy something else first	They feel nervous about it	They are trying to sneakily buy it without their parents knowing
If you purchase an item for $60 and will pay $10 a month to pay it off, how many months will it take you to pay it off?	6 months	2 months	4 months	8 months
What is interest?	The amount you need to pay for borrowing money	A discount you get on paying for an item	A tip you give to the person you're borrowing money from	The amount of time you have to pay off a loan
What is credit?	An agreement to buy a good or service now and pay it back later	A discount given to you by a bank for opening up an account	A weekly amount of money you are given by someone you do work for	A payment plan for a loan taken to buy a house
You want to pay off a $50 item over 10 months. How much will you have to pay each month?	$5	$8	$10	$12

the NAO robot. Overall, there were 16 female participants, 9 male participants, and 1 non-binary participant. Before and after each session, both groups were given identical pre and post-test surveys to assess the knowledge they retained from the exercise Table I. The post-test also included a question to gauge the students' enjoyment of their respective lesson plans. For the experimental group, each student worked individually with a researcher and one of four NAO robots equipped with the lesson plan. During each student's interaction with the robot, data was collected on the frequency at which he or she required hints, repeats, or interventions, as well as the point in the lesson plan at which this intervention was needed.

D. Phase 4: Evaluating the System's Performance

The final phase of the study utilized a system evaluation approach to assess the effectiveness of the robot as a teaching method compared to the traditional worksheet lesson plan. The major goals of the evaluation, as shown in Table II, were to understand (1) the efficacy of the embodied AI system, (2) the robustness and feasibility of the product, and (3) the student's level of enjoyment.

E. Measures

The three aforementioned objectives aimed to ascertain whether integrating robots into financial literacy education for fourth-grade students is viable, taking into account successful implementation, student comprehension, and enjoyment. The data collected to assess the system was both qualitative and quantitative. Qualitatively, the level of enjoyment the participants held was marked through the post-test surveys. Quantitatively, the improvement scores of each participant were derived from the pre and post-test surveys as well as the observed frequency and location of hints, repeats, and interventions in the robot group. This comprehensive data collection allowed for a thorough analysis of the system and the viability of utilizing robots in financial education, given the parameters of the study.

IV. RESULTS AND DISCUSSION

Data used in this analysis was segmented by method to test the efficacy of implementing each method of teaching and measure the robustness of this system. An analysis was performed to understand the distributions of data collected, as well as to test for any significant results.

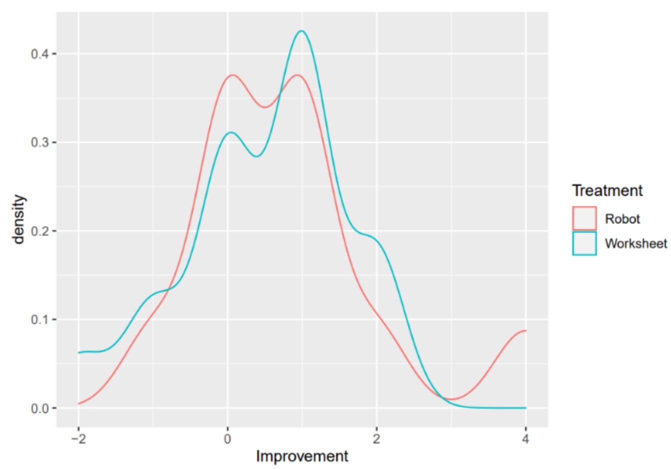

Fig. 3. Comparison of the density plots of improvement in scores between the experimental (robot) and control (worksheet) groups.

A. Efficacy of Embodied AI System

An efficacy analysis of this material was performed by testing in the student's typical environment rather than an idealized one. This method develops results that can demonstrate how these methods would perform in a typical school. To test the efficacy of the robot in teaching students, the students were provided a pre-test and post-test consisting of 5 questions on the material, as seen in Table I. By providing the same assessment twice, we were able to observe any improvement or decline in retention and compare the students' performance in each method. In doing so, we used an improvement metric, subtracting the pre-test score from the post-test score.

The experimental group showed a mean improvement of 0.82, while the control group showed a mean improvement of 0.5. From their density plots, as seen in Fig. 3, we can also see that each group showed a large range of improvements, with one child improving their score by 4 points from the robot and one

TABLE II

Goals of the experimental analysis and their corresponding metrics used for measurement and reasoning for inclusion.

Goal	Metric	Reason
(1) Efficacy of the embodied AI system	Pre and post-test survey grades	To see if students' scores increase based on the teaching method
(2) Robustness and feasibility of the product	Number of repetitions - how many times the student needed the robot to repeat itself	To see how many times the robot was difficult to understand
	Number of hints - how many times the student did not know how to answer the robot's question or did not know the answer	To see how many times the lesson plan was beyond the students' capabilities
	Number of interventions - how many times the research team members had to intervene to aid the students	To see how often supervisor intervention is needed
(3) Level of students' enjoyment in the teaching method	Scale of how much the student enjoyed the lesson from 1-5	To see which teaching incited higher levels of enjoyment amongst students

child performing 2 points worse on the post-test after completing the worksheet.

Because the sample sizes are small, have large outliers, and the distributions appear non-normal, an Anderson-Darling test was performed on both samples to test if non-parametric tests should be used to relax assumptions associated with parametric testing. These tests showed statistically significant results at the $\alpha = .05$ significance level, implying sufficient evidence to reject the null hypothesis that either of these distributions are normal.

A resulting 1-sample Wilcoxon Signed Rank Tests was then performed against the null hypothesis that the median of each group is not greater than 0. Both tests returned statistically significant results at the $\alpha = .05$ significance level, leading us to reject the null hypothesis to state that both the experimental group and the control group had a statistically significant, positive effect on the children's learning. However, a 2-sample Wilcoxon Signed Rank Test aiming to determine if there was any significant difference between the two groups found no significant difference, indicating that we cannot prove any superiority of the experimental robot teaching method over the control method.

B. *Robustness and Feasibility of Product*

To evaluate the robot's performance when interacting with a student, we totaled the number of times a student required assistance from a researcher and where in the lesson plan this intervention occurred. This assistance could occur in the form of a hint, a repeat, or an intervention. We found that, on average, there were more repeats needed compared to hints and interventions. This may be because the robot can be difficult to understand when engaging for the first time. Hints were only available in tandem with questions that involve math problems, which could also be a factor. Nearly a third of the times a student needed help was during a question that involves math.

To evaluate if there is a relationship between the amount of help a student received and their improvement from the pre to post-test, we determined the correlation between these two variables. There is a negative correlation between the two variables with $r = -0.448$ and r^2 This could mean that the more help a student receives, the less likely they are to improve. However, since the r^2 value is not close to 1, the observed correlation is not considered to be strong. Overall, all the students enjoyed the experiment to some extent. However, it is clear that the robot struggles to teach the kids when it comes to math-related content. There were also some difficulties regarding participants' understanding of the robot throughout the lesson plan.

C. *Students' Level of Enjoyment*

Lastly, to test the feasibility of further use of robots in the classroom, it's important to see if children would enjoy the teaching method. The more engaged students are during lessons, the more they will be able to learn, and therefore teaching methods that are enjoyed more may be more effective. To test this, an ordinal scale was developed where children could rate how much they enjoyed the lessons as: "not at all", "a little", "enjoyed it", and "a lot". To test if the students enjoyed the robot more than the worksheet, a 1-sided Wilcoxon Rank Sum Test was performed to see if the median score assigned by students in each group differed. At the $\alpha = .05$ significance level, the results showed that the students in the robot group reported greater enjoyment levels with the lesson, implying the robot was the more engaging tool. One question that can be raised here is whether the robot would continue to be a more engaging tool in future lessons, or if the children's enjoyment associated with the tool would decrease as they used it more frequently. This hypothesis should be addressed by conducting longitudinal studies to evaluate the aforementioned metrics over time.

V. Conclusion and Future Work

Virtual voice assistants and robotics have unlocked a potential new learning method for students. Our team has embedded a virtual voice assistant system into a NAO robot and tested its effectiveness and desire in the classroom. This study focused on a credit and debit lesson plan for fourth-grade students at Greer Elementary School. The experiment results indicate that both the robot and worksheet methods helped in improving students' understanding of the lesson presented. Although the students tended to struggle in comprehension of math-related questions administered by the robot, they were still more engaged overall when interacting with the robot as compared to the worksheet.

The randomly selected experimental group consisted of more students with English as a second language (ESL) than that the control group. Proficiency in English could have contributed to differences in how groups interacted with the system. This research should create foundations for future work to study the use of robots in classrooms with varying levels of ESL students to determine which environments the robots will create the most value in. Another opportunity for potential work is to add the capability to change the language in which the lesson is delivered in.

Future work in the area of AI-enabled voice assistants for education use should involve testing the robot at more elementary schools to gain a larger sample size. Through additional testing, one could identify areas to improve the voice recognition function in the Choregraphe software and the lesson plan itself. The system could also be expanded in the future through further experimentation with different lesson plans, course subjects, grade levels, etc. For instance, more lesson plans could be developed to cover additional financial literacy lessons, lessons adapted to different grade levels or age groups, lessons of varying lengths, lessons in different languages, etc. Another potential area for future work and improvement of the existing system is the introduction of interdisciplinary perspectives in order to improve upon the robot's performance and effectiveness. In an interdisciplinary team, educational experts could provide insight into the language that will be most effective within each age group. Additionally, bias prevention measures could be taken to ensure the system does not exhibit any biases, especially against marginalized groups.

AI systems are exciting, new technologies sure to disrupt modern-day education as we know it. The preliminary testing of our prototype indicated that the system has the potential ability to increase students' enjoyment of a lesson and their retention of the material. However, additional research is needed to provide the necessary insight into the system's effectiveness in the classroom, as well as the best methods of implementation. With additional research, strategies can be developed for overcoming some of the difficulties we faced, such as understanding the robot in a loud, classroom environment and comprehending math questions without aid. Still, this prototype and other systems like it shows promise to become unique, new educational tools.

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